भारतीय मानक
Indian Standard

IS 398 (Part 6) : 2021

शिरोपरी प्रेषण कार्यों के लिए ऐल्यूमिनियम के चालक

भाग 6 उच्च चालकता ऐल्यूमिनियम मिश्रधातु लड़दार चालक — विशिष्टि

Aluminium Conductors for Overhead Transmission Purposes

Part 6 High Conductivity Aluminium Alloy Stranded Conductors — Specification

ICS 29.240.20

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Conductors and Accessories for Overhead Lines Sectional Committee, ETD 37

FOREWORD

This Indian Standard was adopted by the Bureau of Indian Standards after the draft finalized by the Conductors and Accessories for Overhead Lines Sectional Committee had been approved by the Electrotechnical Division Council.

This standard with first version is originally published in 2019, after the need for the standard identified by the Conductors and Accessories for Overhead Lines Sectional Committee to keep pace with the global development and standardization for new aluminum alloys being used in manufacturing Overhead Transmission and Distribution Conductors with improved conductivity.

The first version has been undertaken with the view to effecting the following:

a) To line up with the International Standards.

b) To rationalize the sizes of high conductivity aluminum alloy stranded conductors (aluminum-magnesium-silicon type) to conform the requirements of Indian power utilities.

This Indian Standard is published in six parts. The other parts in this series are:

Part 1 Aluminum stranded conductors.

Part 2 Aluminum conductors, galvanized steel – reinforced.

Part 4 Aluminum alloy stranded conductors (aluminum-magnesium-silicon type)

Part 5 aluminum conductors, galvanized steel – reinforced for extra high voltage.

In this revision the conductor and the alloy wire properties have been rationalized to keep in tune and to ensure compatibility with other Indian Standards for conductors. This aluminium alloy type covered under this standard provides better resistivity compared to the other AL-Mg-Si alloy as per Part 4 of this standard. The standard resistivity value of 0.029 05 ohm mm^2/m at 20 °C has been adopted for arriving at the calculated resistance of the conductors. The temperature coefficient of resistance to be considered as 0.003 8/°C.

The composition of the committee responsible for the formulation of this standard is given at Annex B.

For the purpose of deciding whether a particular requirement of this standard is complied with the final value, observed or calculated, expressing the result of a test or analysis, shall be rounded off in accordance with IS 2 : 1960 ‘Rules for rounding off numerical values (*revised*)’. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

Indian Standard

ALUMINIUM CONDUCTORS FOR OVERHEAD TRANSMISSION PURPOSES

PART 6 HIGH CONDUCTIVITY ALUMINIUM ALLOY STRANDED CONDUCTORS —SPECIFICATION

1 SCOPE

1.1 This standard (Part 6) covers the requirements of special aluminum alloy stranded conductors having lesser resistivity than the aluminum alloy specified in IS 398 (Part 4).

1.2 This standard specifies the requirement of special alloy conductors with specified dimensions and including number of wires, but can also be applied to differently constructed conductors.

1.3 Unless otherwise specified the testing procedure shall be similar to IS 398 (Part 4).

2 REFERENCES

The standards listed below contain provisions which, through reference in this text, constitute provisions of this standard. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this standard are encouraged to investigate the possibility of applying the most recent editions of the standards listed below

IS No	*Title*
398 (Part 2)	Aluminium conductors for overhead transmission purposes — Specification: Part 2 Aluminium conductors, galvanized steel-reinforced
398 (Part 4)	Aluminium conductors for overhead transmission purposes. Part 4 Aluminum alloy stranded conductors (aluminum-magnesium-silicon type) — Specification

3 TERMINOLOGY

All the definitions given in IS 398 (Part 4) are applicable to this standard.

4 PHYSICAL CONSTANTS FOR HIGH CONDUCTIVITY ALUMINIUM ALLOY WIRES

4.1 Density

The density of the high conductivity aluminum alloy wire specified in this standard shall be considered as 2.70 g/cm^3.

4.2 Co-efficient of Linear Expansion

The coefficient of linear expansion for high conductivity aluminum alloy wire specified in this standard is taken as 23×10^{-6}/°C.

4.3 Temperature Coefficient of Resistivity

The temperature coefficient of resistivity of high conductivity aluminum alloy wire specified in this standard is 0.003 80/°C.

5 MATERIAL COMPOSITION

The wire shall be heat treatable Al-Mg-Si alloy, meeting all the requirements on resistivity, Tensile strength, etc. specified in this standard.

6 RESISTIVITY

Resistivity of a material is the resistance of a wire of that material of unit length and unit cross- sectional area. The standard value of resistivity of high conductivity aluminum alloy wire which shall be used for calculation is to be taken as 0.029 05 Ω mm^2/m at 20°C.

7 STRENGTH AND ELONGATION OF WIRE

Strength of the high conductivity aluminum alloy wire specified in this standard is given in Table 1 and Table 2.

Table 1 Mechanical Properties of High Conductivity Aluminium Alloy Wires

(*Clause* 7)

Diameter of Wire (mm)		Minimum Tensile Strength of Wire (N/mm²)		Minimum Elongation on 250 mm (percent) (Before and After Stranding)
Over	Upto and Including	Before Stranding	After Stranding	
-	3.5	250	237.5	2.0
3.5	4.0	240	228.0	2.0
4.0	4.5	230	218.5	2.0

Table 2 High Conductivity Aluminium Alloy Wires Used in the Construction of Stranded Conductors

(*Clause* 7, 9.1.1 *and* 9.1.2)

Diameter			Cross sectional area of nominal wire diameter mm²	Mass kg/km	Minimum Breaking Load		Resistance at 20°C
Nom mm	Min mm	Max mm			Before Stranding kN	After Stranding kN	
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
2.00	1.97	2.03	3.142	8.483	0.79	0.75	9.246
2.50	2.47	2.53	4.909	13.254	1.23	1.17	5.918
2.89	2.86	2.92	6.56	17.712	1.64	1.56	4.428
3.08	3.05	3.11	7.451	20.117	1.86	1.77	3.899
3.18	3.15	3.21	7.942	21.443	1.99	1.89	3.658
3.31	3.28	3.34	8.605	23.234	2.15	2.04	3.376
3.40	3.37	3.43	9.079	24.513	2.27	2.16	3.200
3.52	3.48	3.56	9.731	26.275	2.34	2.22	2.985
3.66	3.62	3.70	10.521	28.407	2.53	2.40	2.761
3.81	3.77	3.85	11.401	30.783	2.74	2.60	2.548
4.02	3.98	4.06	12.692	34.269	2.92	2.77	2.289
4.26	4.22	4.30	14.253	38.483	3.28	3.12	2.038

NOTES

1 The resistance value specified in the above table are only for reference.

2 The resistance value specified in the above table are calculated from the standard resistivity of the single wire specified in **6** and cross-sectional area from the nominal wire diameter.

3 The minimum breaking load before stranding is calculated from the tensile strength of single wire specified in Table 1 and cross-sectional area based on the nominal wire diameter and reduced to 95 percent after stranding.

8 FREEDOM FROM DEFECTS

The wires used for standard conductors shall be smooth and free from all imperfections not consistent with good commercial practice, for example, spills and splits.

9 STANDARD SIZES

9.1 Wires

9.1.1 *Nominal Sizes*

The special aluminum alloy wires for stranded constructions covered by this standard shall have the diameters specified in Table 2.

9.1.2 *Tolerances on Nominal Size*

A tolerance of ±0.03 mm shall be permitted on the nominal diameter up to and including 3.00 mm and ±1 percent shall be permitted on the nominal diameter above 3.00 mm as specified in Table 2 (rounded off).

9.2 Stranded Conductors

9.2.1 *Sizes*

The standard sizes, resistance and mass of special aluminum alloy conductors shall be as given in the Table 3. Tolerances on size/ mass shall be as follows:

a) Outer diameter of conductor : ± 1 percent,; and

b) Overall Mass of conductor : ± 2 percent.

Table 3 High Conductivity Aluminum Alloy Stranded Conductors

(*Clause* 9.2.1)

Sl No. (1)	Actual Area (mm²) (2)	Stranding and wire Diameter (mm) (3)	Approx Overall Dia (mm) (4)	Approx Mass (kg/ km) (5)	Calculated Maximum Resistance at 20°C (Ω/km) (6)	Approx. Calculated UTS (kN) (7)
1	15	3/2.50	5.39	40.15	1.9920	3.50
2	22	7/2.00	6.00	60.15	1.3379	5.20
3	34	7/2.50	7.50	93.98	0.8563	8.20
4	80	7/3.81	11.43	218.28	0.3687	18.20
5	100	7/4.26	12.78	272.88	0.2949	21.80
6	125	19/2.89	14.45	342.55	0.2372	29.60
7	173	19/3.40	17.00	474.09	0.1714	41.0
8	200	19/3.66	18.30	549.39	0.1479	45.60
9	276	37/3.08	21.56	759.20	0.1075	65.47
10	454	61/3.08	27.72	1254.34	0.0653	108.0
11	484	61/3.18	28.62	1337.00	0.0613	115.1
12	525	61/3.31	29.79	1448.61	0.0566	124.70
13	554	61/3.4	30.6	1528.44	0.0536	131.53
14	594	61/3.52	31.7	1638.23	0.0501	135.4
15	642	61/3.66	32.94	1771.16	0.0463	146.40
16	695	61/3.81	34.29	1919.30	0.0427	158.60
17	774	61/4.02	36.18	2136.69	0.0384	169.17

NOTES

1 The maximum resistance value specified in the above table are calculated from the standard resistivity of the single wire specified in clause **6** and cross sectional area from the nominal wire diameter.

2 The actual cross sectional area of the conductor specified in the above table are calculated as sum of the cross sectional area of nominal wire diameter.

3 See Annex A.

10 JOINTS IN WIRES

In stranded conductors containing more than 7 wires, joints in individual wires are permitted in any layer except the outermost layer but no two such joints shall be less than 15 m apart in the complete stranded conductor. Such joint shall be made by cold press butt welding and the strength of the jointed wires shall not be less than 90 percent of the value required for an unjointed wire.

11 STRANDING

11.1 The wire used in the construction of a stranded conductor shall, before and after stranding, satisfy all the relevant requirements of this standard.

11.2 The lay ratio of the different layers shall be within the limits given in Table 4.

11.3 In all constructions the successive layers shall have opposite directions of lay, the outer layer being right handed. The wires in each layer shall be evenly and closely stranded.

11.4 The lay ratio of any layer shall not be greater than the lay ratio of the layer immediately beneath it.

12 LENGTHS AND VARIATIONS IN LENGTHS

12.1 Unless otherwise agreed between the purchaser and the manufacturer, stranded special aluminum alloy conductors shall be supplied in the manufacturer’s usual production lengths and with a permitted variation of ±5 percent in the length of any one conductor length.

12.2 Random Lengths

Unless otherwise agreed between the purchaser and the manufacturer, it shall be permissible to supply not more than 10 percent of the lengths on any one order in random lengths; none of them shall be shorter than one half of the nominal length.

Table 4-Lay Ratios for Special Aluminum Alloy Conductors

(*Clause* 11.2 *and* 16.4)

Number of Wires in Conductor	3/6 Wires Layer		12 Wires Layer		18 Wires Layer		24 Wires Layer	
	Min	*Max*	*Min*	*Max*	*Min*	*Max*	*Min*	*Max*
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
3	10	14	-	-	-	-	-	-
7	10	14	-	-	-	-	-	-
19	10	16	10	14	-	-	-	-
37	10	17	10	16	10	14	-	-
61	10	17	10	16	10	15	10	14

13 PACKING AND MARKING

The conductor shall be wound on reels or drums and marked with the following minimum details:

a) Name of the manufacturer;
b) Size of conductor;
c) Length of the conductor; and
d) Net and gross mass of the conductor.

Material of drum and packaging shall be as agreed between the purchaser and the manufacturer.

13.2 BIS Certification Marking

The product(s) conforming to the requirements of this standard may be certified as per the conformity assessment schemes under the provisions of the *Bureau of Indian Standards Act*, 2016 and the Rules and Regulations framed thereunder, and the products may be marked with the Standard Mark.

14 CLASSIFICATIONS OF TESTS

Type test are intended to verify the main characteristics of a conductor which depend mainly on its design. These tests are normally performed only once for a given conductor construction and shall be carried out if agreed between the purchaser and the manufacturer. Acceptance and Routine tests are intended to guarantee the quality of conductors and compliance with the requirements of this standard.

Type tests, acceptance and routine tests are listed as below:

		Type Test	Acceptance and Routine Test	Clause
Conductor	Visual examination	x	x	16.2
	Measurement of lay ratio	x	x	16.3
	Ultimate tensile strength test	x[1)]	-	16.9
	DC resistance test	x[1)]	-	16.10
	Stress-strain test on conductor	x[1)]	-	16.11
Aluminum Alloy Wires	Measurement of diameter	x	x	16.4
	Breaking load test	x	x	16.5
	Elongation test	x	x	16.6
	Resistivity test	x	x	16.7
	Wrapping test	x	x	16.8

[1)] This test is applicable to conductors of nominal aluminum area 100 mm^2 and above.

15 REJECTION AND RETEST

15.1 Should any one of the test pieces first selected fail to the requirements of the tests, three further samples from the same batch shall be selected for testing, one of which shall be from the length from which the original test sample was taken unless that length has been withdrawn by the supplier.

15.1 Should all of the three test pieces from these additional samples satisfy the requirement of the tests, the batch represented by these samples shall be deemed to comply with the standard .Should the test pieces from any of three additional samples fail ,the lot represented shall be deemed not to comply with standard.

16 TESTS

16.1 Selection of Test Samples for Acceptance, Routine and Type Test

16.1.1 Samples for the tests specified in **16.2**, **16.3**, **16.4**, **16.5**, **16.6**, **16.7** and **16.8** shall be taken by the manufacturer during routine test, from not less than 10 percent of the conductor drums.

16.1.2 For acceptance test, if desired by the purchaser at the time of placing an order that the tests as mentioned in **16.1.1** shall be made in the presence of his representative, samples of wire shall be taken from length of stranded conductors. Samples shall then be obtained by cutting 2 m from the outer end of the finished conductor from not more than 10 percent of the finished reels or drums.

16.2 Visual Examination

The conductor shall be examined visually for good workmanship and general surface finish of the conductor.

16.3 Measurement of Lay Ratio/Direction of Lay

The lay ratio of each layer of the conductor shall be measured and checked as per requirements specified in Table 4 and lay direction shall be as per requirements of **11.3.**

16.4 Measurement of Diameter of Individual Aluminum Alloy wires

One sample cut from each of samples taken under **16.1.1** or **16.1.2** shall be measured using a micrometer having flat surface on both the anvil and the end of the spindle to be read with micrometer. The diameter in millimeter shall be determined by the average of three diameter measurements, each of which shall be the mean of the two measurements at right angles taken at the same cross-section.

The diameter of the wire shall be within limit as specified in Table 2.

16.5 Breaking Load Test

The breaking load of one specimen, cut from each of the sample taken under **16.1.1** or **16.1.2** shall be determined by means of suitable tensile testing machine. The load shall be applied gradually and the rate of separation of the jaws of the testing machine shall be not less than 25 mm/min and not greater than 100 mm/min. The breaking load of wire shall be within limit as specified in Table 2.

16.6 Elongation Test

The elongation of one specimen cut from each of the samples taken under **16.1.1** or **16.1.2** shall be determined as follows.

16.6.1 The specimen shall be straightened by hand and an original gauge length of 250 mm shall be marked on the wire. A tensile load shall be applied as described in **16.5.1** above and the elongation shall be measured after the fractured ends have been fitted together. If the fracture occurs outside the gauge marks, or within 25 mm of either mark, or the required elongation is not obtained, the test shall be disregarded and another test should be made. When tested before and after stranding, the elongation shall be not less than the specified values in Table 1 on a gauge length of 250 mm.

16.7 Resistivity Test

The electrical resistance of one specimen cut from each of the samples taken under **16.1.1** or **16.1.2** shall be measured at ambient temperature. The measured resistance shall be corrected to the value at 20°C by means of the formula:

$$R_{20} = R_T \left[\frac{1}{1+\alpha\ (T-20)} \right]$$

where

R_{20} = resistance corrected at 20°C,

R_T = resistance measured at T°C,

α = constant-mass temperature co-efficient of resistance, 0.0038/°C, and

T = ambient temperature during measurement in °C.

The resistivity shall be calculated from the corrected resistance and measured wire diameter as per clause **16.4** using the following formula:

$$\rho = \frac{A}{L} * R$$

where

ρ = Resistivity,

A = Cross-sectional area of wire,

L = Length of Wire, and

R = Resistance corrected at 20°C.

The maximum value of resistivity of any single wire shall not exceed 0.029 30 Ω mm²/m at 20°C

16.8 Wrapping Test

Wire specimen, cut from each of the sample taken under **16.1.1** or **16.1.2** shall be wrapped round a wire of its own diameter to form a close helix of eight turns at a speed not exceeding 60 turns per minute.

The wire shall not break.

16.9 Ultimate Tensile Strength Test on Stranded Conductor

This test is applicable to conductors of nominal aluminum area 100 mm² and above.

A sample of the finished conductor having a minimum length of 5 m with appropriate fittings at both ends in such a manner as to permit the conductor to take its normal straight line shape.

Circles perpendicular to the axis of the conductor shall be marked at two places on the conductor sample. The load shall be increased at a steady rate up to 50 percent of the ultimate tensile strength of the Conductor and held for one minute. The circles drawn shall not be distorted due to relative movement of strands and the surface shall not depart from its cylindrical shape nor shall the strands move relative to each other so as to get out of place or disturb the longitudinal smoothness of the conductor. The measured diameter at any place shall be not less than the sum of the minimum specified diameter of the individual aluminum and steel strands as indicated in Table 2 of this standard.

Thereafter the load shall be increased at a steady rate up to rated ultimate tensile strength and held for one minute. When so tested, the conductor shall not show any fracture. The applied load shall then be increased until the failing load is reached and the value recorded. A re-test up to a total of three tests, may be made if wire fracture occurs within one centimeter of the end fittings and the tensile strength falls below the specified breaking strength requirement.

16.10 d.c. Resistance Test on Stranded Conductor

This test is applicable to conductors of nominal aluminum area 100 mm² and above.

On a conductor sample of minimum 5 m length two contact-clamps shall be fixed with a predetermined bolt torque. The resistance shall be measured by a Kelvin double bridge or using

micro ohm meter of suitable accuracy by placing the clamps initially zero meter and subsequently one meter apart. The test shall be repeated for at least five readings across the sample length and the average value shall be recorded. The value obtained shall be corrected to the value at 20°C by means of the formula specified in **16.7**. The resistance corrected at 20°C shall conform to the requirements of this Specification.

16.11 Stress-strain Test

The test to be carried out on complete conductor following the procedure specified in **13.11** of IS 398 (Part 2).

ANNEX A

(*Table 3*)

NOTES ON THE CALCULATION OF TABLE 3

A.1 INCREASE IN LENGTH DUE TO STRANDING

When straightened out, each wire in any particular layer of a stranded conductor, except the central wire, is longer than the stranded conductor by an amount depending on the lay ratio of that layer.

A.2 RESISTANCE AND MASS OF CONDUCTOR

A-2.1 The resistance of any length of a stranded conductor is the resistance of the same length of anyone wire calculated from standard resistivity of the single wire specified in **6** and cross-sectional area from the nominal wire diameter multiplied by a constant as set out in Table 5.

A-2.2 The mass of each wire in any particular layer of stranded conductor, except the central wire, will be greater than that of an equal length of straight wire by an amount depending on the lay ratio of that layer (*see* **A-1.1**). The total mass of any length of an aluminum stranded conductor is, therefore, obtained by multiplying the mass of an equal length of straight wire by an appropriate constant, as set out in Table 5.

A-2.3 In calculating the stranding constants in Table 5, the mean lay ratio that is the arithmetic mean of the relevant minimum and maximum values in Table 4, has been assumed for each layer.

A.3 CALCULATED ULTIMATE TENSILE STRENGTH (UTS) OF CONDUCTOR

The strength of conductor in terms of individual component wires shall be taken as 95 percent of the sum of strengths of the individual wire calculated from the values of the minimum breaking load given in col 6 of Table 2.

Table 5 Stranding Constants

(*Clauses* A-2.1,A-2.2, and A-2.3)

Number of Wires In Conductor	Stranding Constants	
	Mass	Electrical Resistance
(1)	(2)	(3)
3	3.029	0.3366
7	7.091	0.1447
19	19.34	0.05357
37	37.74	0.02757
61	62.35	0.01676

ANNEX B

COMMITTEE COMPOSITION

Conductors and Accessories for Overhead Lines Sectional Committee, ETD-37

Organization	*Representative(s)*
Power Grid Corporation of India Limited, Gurgaon, Haryana	Shri Anish Anand (***Chairman***)
Adani Group, Ahmedabad, Gujarat	Shri Ishwar Kailashnath Dubey Shri Sujalkumar Bipinchandra Shah (*Alternate* I) Shri Sanket Barapatre (*Alternate* II)
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Apar Industries Limited, Vadodara, Gujarat	Shri S. K. Jana Shri Pradeep Agnihotri(*Alternate*)
Bharat Aluminium Company Limited, Korba, Chatisgarh	Shri Lokesh Kumar Sharma Ms Bhaktilaxmi Sahoo (*Alternate*)
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Modern Malleable Limited, Kolkata, West Bengal	Shri B. N. Jhunjhunwala Shri Archit Jhunjhunwala (*Alternate*)
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Organization	*Representative(s)*
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Member Secretary

Shri P. V. Mathew
Scientist ‘E’ (ETD), BIS

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